EFFECTS OF VARIOUS PLANTERS ON EMERGENCE AND SEED DISTRIBUTION UNIFORMITY OF SUNFLOWER

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ABSTRACT. *In this study, four different type seeders were evaluated for seed spacing, depth uniformity, and plant emergence at three forward speeds (3.6, 5.4, and 7.2 km h^{-1}). The planter types were: no-till planter, precision vacuum planter, universal planter, and semi-automatic potato planter. The sowing uniformity of the horizontal distribution of seeds was described by using the multiple index, the miss index, the quality of feed index, and the precision in addition to the means and standard deviations of the sample methods. Uniformity of planting depth of seeds was described using the mean, standard deviation and the coefficient of variation of the sample methods. Plant emergence ratios were evaluated by mean emergence time, emergence rate indexes, and emergence percentage. The best seed spacing uniformity and seed emergence ratio were obtained with the no-till planter, and the best seed depth uniformity was obtained with the precision vacuum planter. Forward speed significantly affected only the mean emergence time (P < 0.05). As forward speed increased, mean emergence time decreased.*

Keywords. *Planters, Seeders, Sunflower, Seed distribution, Emergence.*

The main objective of seeding is to put seeds at a desired depth and spacing within the row. Uniform seed spacing and depth result in better germination and emergence and increase yield by minimizing competition between plants for available light, water, and nutrients (Griepentrog, 1998; Karayel and Ozmerzi, 2002). The quality of horizontal and vertical distribution of seeds is influenced by row spacing, sowing depth, soil conditions, seeder design, seed density, and operator skill (Griepentrog, 1998).

The mean spacing ($\overline{X}$), the standard deviation of the spacing between plants (SD), and the coefficient of variation (CV) are commonly used for describing seed spacing uniformity. The mean spacing is influenced by seed or plant density and longitudinal distribution. For common grain drills, a CV of 20% is an acceptable accuracy achieved by mechanical and pneumatic machines when they are performing well (Griepentrog, 1998).

The mean spacing and the standard deviation of the seed spacing are useful but do not completely characterize the distribution of plant spacing for single seed planters. The multiple index, the miss index, the quality of feed index, and the precision should be considered in addition to the mean and standard deviation of the seed spacing, because the distance between plants within a row is influenced by a number of factors including multiple seeds dropped at the same time, failure of a seed to be dropped, failure of seeds to emerge, and the variability around the drop point (Kachman and Smith, 1995).

Karayel and Ozmerzi (2002) stated that the best sowing uniformity, the most uniform sowing depth, and maximum emergence percentage occurred when a precision seeder was used after preparing the soil with a moldboard plow, disc harrow, and roller. Different tilling conditions had no effect on the multiple index, the miss index, and the quality of feed index.

Jasa and Dickey (1982) showed that relative surface roughness, amount of residue present, level of preplant tillage, and tillage system were important factors affecting corn seed spacing uniformity in 100 Nebraska fields using nine brands and 35 models of planters. They also concluded that no-till planting could provide at least as uniform a seed spacing as other tillage systems and found that seed spacing uniformity was not affected by planter forward speed, which ranged from 4.8 to 11.2 km/h.

Panning et al. (2000) evaluated sugar beet planting performance for a precision planter designed for shallow planting of small seeds, a general purpose planter designed for row crops, and a vacuum metering general purpose planter designed for row crops that was equipped with three seed tube designs. In their field study, the most uniform seed spacing for each planter configuration occurred at the lowest speed, which was 3.2 km/h. For all planter configurations, the seed spacing uniformity decreased as the forward speed increased from 3.2 to 8.0 km/h. Seed spacing uniformity determined in laboratory tests was greater than, or equal to, seed spacing uniformity determined in field tests.

A sunflower planter was developed by attaching an inclined plate metering mechanism for larger seeds to an existing nine-row seed-cum fertilizer drill (Chauhan et al., 1999). Mean seed spacings were affected only slightly by forward speed, as the means were 28.6, 29.7, and 29.6 cm for forward speeds of 2, 3.5, and 5 km/h, respectively. The

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coefficients of variation were 6.5%, 5.9%, and 8.7% for the travel speeds of 2, 3.5, and 5 km/h, respectively, so the variation in seed spacing was lowest at the intermediate speed of 3.5 km/h, and greater at 2 and 5 km/h.

Effects of plant spacing uniformity on sunflower yield in Minnesota were determined by Robinson et al. (1982). Uniformly spaced single plants lodged the least, produced heads of lowest moisture content at harvest, gave the greatest seed yield, and greatest seed oil content. Yield reductions from uneven plant distributions ranged from 0 to 31% and averaged 10%.

An inclined plate planter was evaluated for metering peanut seeds using planting speeds of 1.6, 3.2, and 4.8 km/h (Chhinnan et al., 1975). As planter speed increased, the average seed spacing increased and the seed placement index increased, meaning the uniformity of seed spacing decreased.

The objectives of this study were to compare sunflower seed spacing and depth uniformity of four different types of planters and three forward speeds and to determine effects of planter type and forward speed on seed emergence under field conditions.

Materials and Methods

This study was conducted at the Research and Application Land of General Directorate of Rural Services Erzurum Research Institute, Erzurum, Turkey. The experiment was designed as a randomized complete block with plots 40 m long and 10 m wide. Some physical properties of the experimental field are given in table 1. Four different types of planters and three forward speeds were considered as treatments and three replications were used. The four planter types were a precision vacuum planter (Hassia Unisem, Hassia Maschinenfabrik GmbH, Butzbach, Hessen, Germany), a no-till planter (Amazonen NT 250, Amazonen-Werke H. Dreyer GmbH & Co., Hasbergen, Germany), a universal planter (Amazonen D8-30 Special, Amazonen-Werke H. Dreyer GmbH & Co., Hasbergen, Germany), and a semi-automatic potato planter (locally manufactured in Turkey). Schematic drawings of the planters are shown in figure 1 and some characteristics of the planters are given in table 2. Except for no-till planting, preplanting tillage was performed using a rotary tiller after harvesting wheat.

No-till planters, precision vacuum planters, and universal planters are general-purpose planters designed for row crops. Semi-automatic potato planters are used by farmers in the study region for both potato and sunflower planting. The seed metering system on each planter was adjusted for a target seed spacing of 0.4 m in the row and 0.7 m between rows. The average vacuum level, hole diameter, and hole spacing in the metering disk for the vacuum planter was 6 kPa, 3.5 mm, and 12°, respectively. The planting rate was 5.3 kg ha^{-1}. The target seed depth was 40 mm for sunflower seeds.

Sunflower seeds were of the snack variety. The weight of 1000 seeds, purity, and the germination rate were 148 gm, 95%, and 96%, respectively. Each planter was operated at three forward speeds (3.6, 5.4, and 7.2 km h^{-1}). The lowest speed was recommended for best seed spacing uniformity, while the highest speed was generally preferred by producers (Panning et al., 2000).

Spacing measurements were performed on a 5-m length of row on at least four rows in each plot, after each plot was planted. Seed spacing was measured following both seeding and emergence. Soil was carefully removed from above the seeds with a flat knife and seed spacing and depth were then measured with a measuring tape. After plant emergence, the spacing was measured again. Seedling counts were made 10, 13, 16, 19, and 22 days after sowing, on 5-m lengths of row in four rows.

The multiple index, the miss index, the quality of feed index, the precision, and the mean and standard deviation of plant spacing were used to quantify the distribution of plant spacing. The multiple index (MULI) is the percentage of occasions where seed spacing was less than or equal to half of the theoretical spacing. The miss index (MISI) is the percentage of occasions where seed spacing was greater than 1.5 times the theoretical spacing. Quality of feed index (QTFI) is the percentage of occasions where seed spacing was more than half but no more than 1.5 times the theoretical spacing and is a measure of the percentage of single seed drops. Precision (PREC) is a measure of the variability in spacing between plants after accounting for variability due to dropping more than one seed at a time and not dropping a seed.

Mean emergence time (MET), emergence rate indexes (ERI), and percentage of emergence (PE) were determined using the following equations (Karayel and Ozmerzi, 2002);

$$MET = (N_1 T_1 + N_2 T_2 + \ldots N_n T_n)/(N_1 + N_2 + \ldots N_n) \quad (1)$$

$$ERI = S_{te}/MET \quad (2)$$

$$PE = 100\% \times S_{te}/n \quad (3)$$

where

$N_{1\ldots n}$ = number of seedlings emerging since the time of previous count

$T_{1\ldots n}$ = number of days after sowing

S_{te} = number of total emerged seedlings per meter

N = number of seeds sown per meter.

Data were analyzed using the SAS statistical software package (SAS Institute Inc., Cary, N.C.). The ANOVA procedure was used to perform the analysis of variance, which was appropriate for a randomized complete block design. Means were compared using Duncan's multiple range tests. Statistical significance was evaluated at the $P < 0.05$ level.

Results and Discussion

Effects of planters and forward speeds on seed spacing uniformity, depth uniformity, and seed emergence ratios

Table 1. Soil physical properties for the 0- to 0.1-m depth range.

Physical Property	Value
Bulk density (Mg m^{-3})	1.43
Porosity (%)	46.1
Moisture content (% d.b.)	17.8
Penetration resistance (MPa)	0.931
Textural class	Sandy clay loam
Soil particular size < 8 mm (%)	61.82

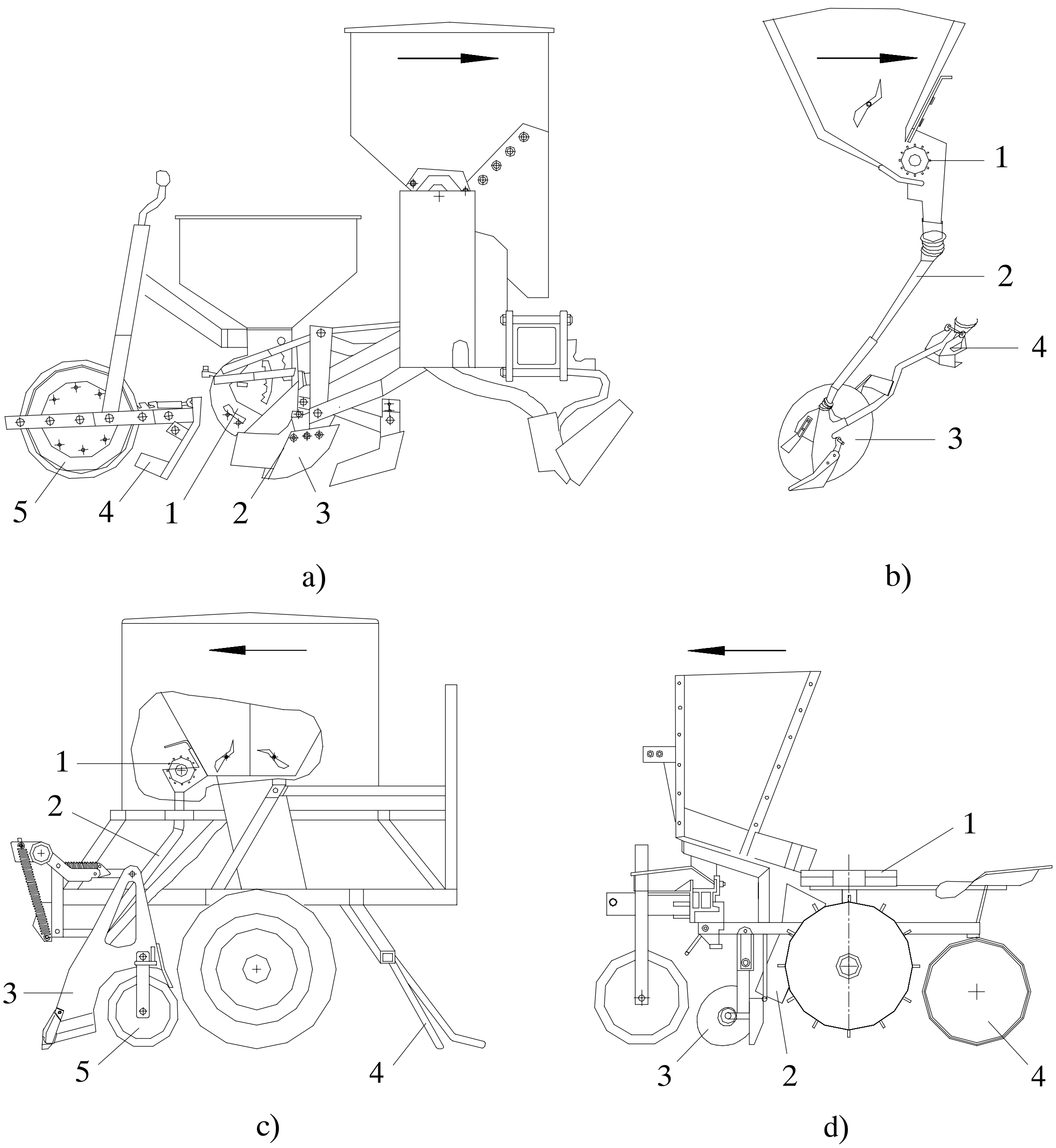

Figure 1. Side views of planters: (a) precision vacuum planter, (b) universal planter, (c) no-till planter, (d) semi-automatic potato planter (1-metering unit, 2-seed drop tube, 3-furrow opener, 4-coverer, 5-press wheel; arrow denotes direction of travel).

were evaluated considering all the parameters. The results of the statistical analysis are given in tables 3 to 5. The results of the analysis on seed spacing uniformity indicated that the planters' effect on the mean seed spacing, standard deviation, miss index, and quality of feed index were statistically significant ($P < 0.05$). On the contrary, coefficient of variation, multiple index, and precision were not influenced by the planter type. The effects of forward speed and forward speed × planter interactions were not statistically significant for all parameters except MET. This lack of a significant effect of forward speed on seed placement is contrary to most literature and may have resulted from greater variability in the seed placement, compared to experiments reported in the literature. The smallest mean of the miss index, indicating the smallest percentage of seed spacings that were greater than the theoretical spacing, and the largest mean of quality of

Table 2. Specification of planters used for sunflower seeding.

	Planter Type			
Specification	Precision Vacuum (Hassia)	No-till (Amazonen)	Universal (Amazonen)	Semi-automatic Potato Planter
Number of rows	4	4	4	2
Spacing between rows (m)	0.70	0.76	0.70	0.70
Seed metering device	Seed cell wheel	Studded seed roller	Studded seed roller	Horizontal spacing wheel
Furrow opener type	Shoe	Hoe	Disc coulter	Disc coulter
Weight per row unit (kg)	188	350	93	60

Table 3. Analysis of variance (P values) and means comparisons of seed spacing values.

Source	DF	Mean	SD	CV	MULI[a]	MISI	QTFI	PREC
Planter (P)	3	<0.01[b]	0.05	0.13	0.07	<0.01[b]	<0.01[b]	0.07
Speed (S)	2	0.76	0.71	0.83	0.83	0.63	0.99	0.85
P × S	6	0.74	0.73	0.73	0.95	0.81	0.98	0.86

	Mean Comparisons					
Planter	Mean (mm)	CV (%)	MULI (%)	MISI (%)	QTFI (%)	PREC (%)
Precision vacuum planter	505.7 a[c]	52.6	11.9	27.2 a	60.9 b	32.9
No-till planter	381.2 b	45.6	11.9	5.1 c	83.0 a	29.7
Universal planter	379.6 b	55.1	18.7	10.2 bc	71.1 b	31.4
Semi-automatic potato planter	407.6 b	64.0	19.3	14.2 b	66.6 b	31.9

[a] MULI is the multiple index, MISI is the miss index, QTFI is the quality of feed index, and PREC is the precision.
[b] Significance level < 0.01.
[c] Means within the same column followed by the same letter are not significantly different ($\alpha = 0.01$). Also, within each column, means followed by two letters (e.g. bc) are not significantly different from means followed by either of those individual letters (b or c).

feed index occurred for the no-till planter. Based upon the miss index and quality of feed index, the no-till planter produced the best seed spacing uniformity. The universal planter was the second best, the potato planter was the third best, and the precision vacuum planter was the worst (table 3).

The largest mean spacing was obtained with the precision vacuum planter, while the mean spacings for the other three planters were similar to one another. For the 0.4-m target value of seed spacing, the potato planter produced the best mean spacing. The seed metering system on the potato planter differed from all others, as the potato planter had no mechanical device that would obstruct flowing seed. Workers placed seed on a horizontal spacing wheel and the rotation of the spacing wheel was driven by a drive wheel. Seed metering was affected mainly by workers' ability and durability. For this reason, the potato planter had the greatest CV while the best CV occurred for the no-till planter.

The relatively high miss index and mean seed spacing of the precision vacuum planter probably were largely caused by the oblong, pointed shape of the sunflower seeds. The precision vacuum planter is a general planter for crops including sunflowers, corn, soybeans, beans, lentils, and chickpeas. The seed metering disk that was used in the precision vacuum planter was recommended for use with various crop seeds and was not specifically for only sunflower seeds. Sunflower seeds are oblong and typically have one end that is more pointed than the other end. They are considerably less spherical than soybean seeds and are typically more oblong than corn seeds. Also, the sunflower seeds used in this experiment were of the snack variety, and they are typically longer and larger overall than oilseed sunflower seeds. The snack variety of sunflower seeds are less spherical than oilseed sunflower seeds.

The seed metering disk of the precision vacuum planter probably did not pick up and hold the sunflower seeds against the holes of the disk as well as some other crop seeds would be held because the oblong shape and pointed ends of the sunflower seeds likely reduced the forces that held the seeds against the disk, compared to the forces for seeds that are more spherical, and because the disk was not designed specifically for sunflower seeds. These factors are expected to cause decreases in seed spacing uniformity because seeds that are not held firmly against the seed metering disk would be more likely to fall off of the disk prematurely. This likely caused some seeds to fall off of the disk before the holes were in the position where the seeds were meant to be released and this would increase both the miss index and the mean seed spacing.

Correlations between QTFI and MULI, and between QTFI and MISI were tested because QTFI = 100 – (MULI + MISI). There was a significant correlation between QTFI and MULI ($r = -0.81$; $P = 0.0001$). The correlation between QTFI and MISI was not important ($r = -0.39$; $P = 0.06$) statistically. While MULI and MISI increased, QTFI decreased. QTFI, MULI, and MISI were calculated as proportions. Such data need transformations to make the distribution more symmetric. After applying a square root transformation to these parameters, statistical analysis was performed (Schabenberger, 1996).

While the seed depth uniformity was significantly affected by planter type, the forward speed and forward speed × planter interaction's effects on the depth were not significant. The mean and standard deviation of the sowing

Table 4. Analysis of variance (P values) and means comparisons of seed depth uniformity.

Analysis of Variance					Mean Comparisons			
Source	DF	Mean	SD	CV	Planter Type	Mean (mm)	SD (mm)	CV (%)
Planter (P)	3	<0.01[a]	<0.01[a]	0.07	Precision vacuum	58.0 b[b]	9.8 b	17.1
Speed (S)	2	0.29	0.79	0.79	No-till	48.5 b	11.5 b	23.8
P × S	6	0.76	0.69	0.78	Universal	33.6 c	12.4 b	41.3
Error	12				Semi-automatic potato planter	102.8 a	29.9 a	30.0

[a] Significance level < 0.01.
[b] Means within the same column followed by the same letter are not significantly different ($\alpha = 0.05$).

Table 5. Analysis of variance (P values) and means comparisons for seed emergence values.

Analysis of Variance				Mean Comparisons			
Source	MET[a]	ERI	PE	Planter Type	MET (d)	ERI (seedlings d^{-1} m^{-1})	PE (%)
Planter (P)	<0.01[b]	0.01[c]	0.02[c]	Precision vacuum	14.4 d[d]	0.33 b	58.5 b
Speed (S)	0.02[c]	0.64	0.89	No-till	14.8 c	0.55 a	86.7 a
P × S	0.38	0.52	0.72	Universal	15.3 a	0.35 b	67.5 b
				Semi-automatic potato planter	15.0 b	0.42 b	71.3 ab

	Mean Comparisons for Forward Speeds		
	3.6 km h^{-1}	5.4 km h^{-1}	7.2 km h^{-1}
MET (d)	15.0 a[e]	14.8 b	14.8 b
ERI (seedlings d^{-1} m^{-1})	0.38 a	0.43 a	0.42 a
PE (%)	72.5 a	71.4 a	69.2 a

[a] MET is the mean emergence time, ERI is the emergence rate indexes, and PE is the percentage of emergence.
[b] Significance level < 0.01.
[c] Significance level < 0.05.
[d] Means within each column followed by the same letter are not significantly different (α = 0.05). Also, within each column, means followed by "ab" are not significantly different from means followed by "a," "b."
[e] Means within the same row followed by the same letter are not significantly different (α = 0.05).

depth were found to be significant (P < 0.01). The most uniform sowing depth was obtained with the precision vacuum planter. The standard deviation and CV of the depth of the precision vacuum planter were 9.8 mm and 17.08%, respectively. The actual planting depths for the precision vacuum, no-till, and potato planters were 45%, 21%, and 157% greater than the target depth, respectively. The potato planter caused a much greater seed depth because the pair of disks at the rear of the planter (fig. 1) deposited a considerable amount of soil above the seeds, forming a ridge of soil over the seeds. The planting depth for the universal planter was 16% less than the target seeding depth (table 4).

The sunflower emergence data are results from one year and three replications. Planter effects on evaluation parameters for emergence, MET, ERI, and PE were statistically important (P < 0.05). The greatest total percentage of emergence was 86.7% and occurred for the no-till planter while the smallest emergence was 58.5% and occurred for the precision vacuum planter. Planter forward speed was statistically important (P < 0.05) only for MET. While forward speed increased, MET decreased. Interactions between planters and forward speeds for MET, ERI, and PE were not important. The greatest total percentage of ERI was found with 5.4-km h^{-1} speed while the smallest was found with 3.6 km h^{-1}. As forward speed increased, PE decreased (table 5).

Conclusions

The type of planter used for planting sunflower seed was found to be important in affecting the miss index, the quality of feed index, the mean seed spacing, the standard deviation, the mean emergence time, the emergence rate indexes, and the percentage of emergence (P < 0.05). The analysis of factors affecting seed spacing uniformity indicated that the best seed spacing uniformity results were obtained with a no-till planter. A universal planter was the second best, and a potato planter was the third best planter. Contrary to the seed spacing uniformity results, the best depth uniformity was obtained with a precision vacuum planter. The no-till planter was the second best and the potato planter was the third best planter. For the results of one year and three replications, the best seed emergence ratios were achieved by the no-till planter, the potato planter, the universal planter, and the precision vacuum planter, respectively. Forward speed significantly affected only mean emergence time (P < 0.05). As forward speed increased mean emergence time decreased and the shortest mean emergence time was obtained at the greatest forward speed.

References

Chauhan, A. M., B. S. Bhatia, and H. S. Dhingra. 1999. Seed placement behaviour of sunflower planter. *Agricultural Mechanization in Asia, Africa and Latin America* 39(4): 9-15.

Chhinnan, M. S., J. H. Young, and R. P. Rohrbach. 1975. Accuracy of seed spacing in peanut planting. *Transactions of the ASAE* 18(5): 828-831.

Griepentrog, H. W. 1998. Seed distribution over the area. *EurAgEng.* 98-A-059, Oslo.

Jasa, P. J., and E. C. Dickey. 1982. Tillage factors affecting corn seed spacing. *Transactions of the ASAE* 25(6): 1516-1519.

Kachman, S. D., and J. A. Smith. 1995. Alternative measures of accuracy in plant spacing for planters using single seed metering. *Transactions of the ASAE* 38(2): 379-387.

Karayel, D., and A. Ozmerzi. 2002. Effect of tillage methods on sowing uniformity of maize. *Canadian Biosystems Engineering* 44: 2.23-2.26.

Panning, J. W., M. F. Kocher, J. A. Smith, and S. D. Kachman. 2000. Laboratory and field testing of seed spacing uniformity for sugarbeet planters. *Applied Engineering in Agriculture* 16(1): 7-13.

Robinson, R. G., J. H, Ford, W. E. Lueschen, D. L. Rabas, D. D. Warnes, and J. V. Wiersma. 1982. Response of sunflower to uniformity of plant spacing. *Agronomy Journal* 74(2): 363-365.

SAS. 1999. *SAS User's Guide: Statistics* Version 8.02. Cary, N.C.: SAS Institute, Inc.

Schabenberger, O. 1996. Analysis of variance with counts and proportions. Available at: http://home.nc.rr.com/schabenb/ANOVACounts.htm. Accessed 22 June 2006.